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I, (Name and address of applicant, and in case of body corporate-place of incorporation)

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(English)

משאבה פריסטלטית

Peristaltic pump

Hereby apply for a patent to be granted to me in respect thereof.

מבקש בזאת כי ניתן לי עלייה פטנט

דרישת דין קדימה*

Application of Division	* בקשה חלוקה		* בקשה פטנט מוסף		* בקשה פטנט מוסף		Priority Claim		
	מבקש פטנט from application	No.	מස'	No.	מස'	לבקשתה/לפטנט to Patent/App.	מזהה סימן Number/Mark	תאריך Date	מדינת האיגוד Convention Country
No. _____	מזהה	מזהה	Dated	מיום	Dated	מיום			
P.o.A.:	* יופיע בה: עוז יוגש		* יופיע בה: עוז יוגש						
C. 140027		המען למסירות מסמכים בישראל Address for Service in Israel							
REINHOLD COHN AND PARTNERS Patent Attorneys P.O.B. 4060, Tel-Aviv		ריינולדז כהן ושותפיו עורכי פטנטים ת"ד 4060, תל-אביב							
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<i>Ben Spengler</i>						לשימוש הלשכה For Office Use			

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משאבה פריסטטוטית

Peristaltic pump

Q-CORE Ltd.

קיו-קור בע"מ

C. 140027

PERISTALTIC PUMP

FIELD OF THE INVENTION

This invention relates to devices for controlling fluid flow.

BACKGROUND OF THE INVENTION

Peristaltic pumps are used for controlling the flow of a fluid in an elastic 5 tubular conduit. These pumps have many medical and industrial applications.

In one form of peristaltic pumps, a rotor is used to rotate a plurality of eccentric cams. Each cam, in turn, intermittently collapses the elastic conduit at an initial contact point, and slides along the conduit over a short distance as the rotor turns. A second cam contacts the initial contact point and the first cam is then 10 released from the conduit as the second cam slides along the conduit. As this process is repeated, a flow of fluid in the conduit is generated in the direction of the sliding of the cams.

U.S. Patent No. 5,996,964 to Ben-Shalom discloses a peristaltic pump in which a plurality of electromagnets are arranged along an elastic conduit. The 15 electromagnets are activated according to a temporo-spatial scheme in order to generate undulations along a magnetizable membrane that is disposed along the conduit. The undulations in the membrane generate undulations in the wall of the conduit, which in turn generate a flow of fluid in the conduit.

SUMMARY OF THE INVENTION

20 The present invention provides a peristaltic pump for generating a flow of fluid in a elastic tubular conduit. The pump comprises a plurality of electrically operated valves that are arranged along the conduit. Each valve has a valve head that alternates between two positions, referred to herein as the "up position" and a

"down position". The designations "up", "down", "left" and "right" are used herein only for the sake of clarity in describing the invention, and the invention is not limited to any particular orientation. When a valve head is in its down position, the valve head presses on a segment of the conduit so as to obstruct the lumen of the 5 conduit in the segment, thus preventing fluid from entering the segment. When the valve head is in its up position, the lumen of the conduit in the segment is open, and fluid may flow into the segment.

Electric power from a power supply is distributed among the valves according to a predetermined temporo-spatial pattern by a driver unit. This 10 generates a temporo-spatial array of valve head positions, which in turn generates a flow of fluid in the conduit.

The invention thus provides a pump for generating fluid flow in an elastic tubular conduit having a lumen, comprising:

- (a) a plurality of electrically operated valves, each valve being positionable 15 adjacent to the conduit, each valve having a valve head, the valve head configured to alternate from a first position in which the lumen of the conduit adjacent to the valve head is unobstructed and a second position in which the lumen of the conduit adjacent to the valve head is obstructed;
- (b) a driver configured to control the positions of the valve heads, so as to 20 execute a predetermined temporo-spatial array of valve head positions.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in 25 practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a peristaltic pump in accordance with one embodiment of the invention;

Fig. 2 shows a valve used in the pump of **Fig. 1**;

Fig. 3 shows a temporo-spatial array of valve activation for a pump having three valves in accordance with one embodiment of the invention;

Fig. 4 shows a temporo-spatial array of valve activation for a pump having 4 valves in accordance with another embodiment of the invention;

5 Fig. 5 shows a peristaltic pump having 4 valves arranged in two dual valves in accordance with another embodiment of the invention;

Fig. 6 shows the construction of a dual valve;

Fig. 7 shows a peristaltic pump in accordance with another embodiment of the invention;

10 Fig. 8 shows the pump of Fig. 7 in conjunction with an elastic tubular conduit held in a sleeve; and

Fig. 9 shows a pump in accordance with another embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

15 Fig. 1 shows schematically a peristaltic pump generally referred to as 10 in accordance with one embodiment of the invention. The pump 10 is used to generate a flow of fluid in a tubular conduit 12 having an elastic wall. The tubular conduit 12 may have any cross-sectional shape such as circular, square, rectangular, and so on. A plurality of electrically operated valves 14 are arranged along the 20 conduit 12. Electric power from a power supply 16 is distributed among the valves according to a predetermined temporo-spatial pattern by a driver unit 18 via cables 20.

Fig. 2 shows the structure of the valve 14 in detail. The valve 14 comprises an electromagnet formed from a wire coil 24. A permanent magnet 28 is attached 25 to a valve head 30. When current flows in a first direction in the coil 24, a magnetic field is generated that raises the magnet 28 and head 30 so as to position them proximate to the electromagnet 24 as shown in Fig. 2a. When current flows in the opposite direction in the coil 24, a magnetic field is generated that lowers the

magnet 28 and head 30 so as to position them distal to the electromagnet 24, as shown in Fig. 2b. The coil 24 is enclosed in a cylindrical housing 32. Guide rods 34 maintain the head 30 coaxial with electromagnet 24 as the head travels from the position shown in Fig. 2a (referred to herein as the "*up position*") to the position 5 shown in Fig. 2b (referred to herein as the "*down position*").

As shown in Fig. 2, the head 30 may have a rectangular cross-section when viewed along the longitudinal axis of the coil 24. This is by way of example only, and the head 30 may have any shape as required in any particular application. For a head having a rectangular cross section, one dimension of the rectangular 10 cross-section (indicated by y in Fig. 2) is selected to be slightly larger than half the circumference of the conduit 12 (i.e. slightly larger than the width of the conduit when flattened).

Referring again to Fig. 1, the valves 14 are oriented adjacent to the conduit 12 with the y dimension perpendicular to the axis of the conduit 12. The other 15 dimension of the head 30 (indicated by x in Figs. 1 and 2) is parallel to the axis of the conduit 12. As seen in Fig. 1, the x-dimension may be different for different valves. Thus, for example, the x-dimension of valve 14a is greater than the x-dimension of valve 14b. The head of the valve 14a, for example, is shown in its up position. The head of the valve 14d is shown in its down position.

20 When a valve head is in its down position, the lumen of the segment adjacent to the valve is obstructed, and fluid cannot flow into the segment. As shown in Fig. 1, the valve head preferably contacts the conduit 12 obliquely, for example by an angle θ of about 4° . Due to the elasticity of the conduit, when a valve head is brought from its down position to its up position, the lumen of the 25 segment of the conduit adjacent to the valve becomes unobstructed, and fluid may flow into that segment of the conduit. The elastic conduit 12 is preferably pre-loaded by limiting the elastic expansion of a segment of the conduit when the valve head adjacent to the segment is brought from its down position to its up

position, so that some elastic strain is always present in all segments of the conduit adjacent to valve heads. This decreases the variability in the volume flow that occurs when a valve moves from one position to another.

The driver 18 is configured to determine the polarity of a voltage applied to 5 the coil 24 of each valve 14 according to a predetermined temporo-spatial array of voltages, so as to generate the temporo-spatial array of the positions (up or down) of the valve heads 30 that generates a flow of fluid in the conduit 12.

Fig. 3 shows schematically an example of a temporo-spatial array of valve activation that may be used with the pump of the invention. This is by way of 10 example, and any temporo-spatial array of valve positions that generates a flow of fluid in the conduit 12 may be used with the pump of the invention. The example of Fig. 3 relates to a pump having three valves. This, however, is only to simplify the explanation of the operation of the pump, and, a pump in accordance with the invention may have any number of valves. For simplicity, only the valve heads 40a, 15 40b and 40c of the valves is shown in Fig. 3.

In the initial configuration 51 of the valve heads, the three valve heads 40a, 40b and 40c are in their down position so that the lumen of the conduit 12 is obstructed in the segments of the conduit 12 adjacent to the valve heads 40a, 40b, and 40c. In stroke 52, the valve head 40a is brought to its up position, so that the 20 lumen of the conduit 12 is open under the valve 40a. The pump now has the configuration 53. Stroke 52 causes fluid to flow into the conduit 12 in the portion of the lumen that was opened by raising valve 40a from its down position to its up position. The flow of fluid is from left to right under the valve head 40a. The volume of fluid that flows is proportional to the x-dimension of the head of the 25 valve 40a. In stroke 54, valve head 40b is raised to its up position, so that the pump acquires the configuration 55. Stroke 54 causes fluid to flow into the segment of conduit 12 that was opened by raising valve 40b from its down position to its up position. No fluid flows out of the pump during stroke 54. In stroke 56, valve head

40a is lowered. Stroke 56 causes an amount of fluid that is proportional to the x-dimension of the valve head 40a to flow from left to right under the valve head 40b. The pump now has the configuration 57. In stroke 58, valve head 40c is raised to its up position, so that the pump assumes the configuration 59. Stroke 58 causes 5 an amount of fluid proportional to the x-dimension of the valve head 40c to flow in the negative direction under the valve head 40c.

In stroke 60, valve head 40b is lowered causing an amount of fluid proportional to the x-dimension of the valve head 40b to flow in the positive direction. The pump thus acquires the configuration 61. In stroke 62, the valve 40c 10 is lowered, causing 1 volume unit to flow in the positive direction. The valve heads 40 are now all in their down position, and the cyclic temporo-array may begin again.

Fig. 4 shows a temporo-spatial array for activating a pump having 4 valves. For convenience, a valve head in its down position is represented as a 1, and a 15 valve in the up position is represented as a 0. The four valve heads are referred to as a_1 , a_2 , a_3 , and a_4 . This array begins with valve heads a_1 and a_2 in their down position, and valve heads a_3 and a_4 in their up position (configuration 500). In the first stroke of the pump (stroke 505), valve head a_1 is raised and valve a_3 is lowered, and the pump acquires the configuration 510. Valve head a_2 is then raised 20 and valve a_4 is lowered (stroke 515) so that the pump acquires the configuration 520. Valve head a_1 is then lowered and valve head a_3 is raised (stroke 525) leading to configuration 530. Valve head a_2 is then lowered and valve head a_4 is raised (stroke 535). The configuration of the pump thus returns to configuration 500, and the cycle may begin again.

25 Fig. 5 shows a pump 600 in accordance with another embodiment of the invention that executes the temporo-spatial array of valve activation shown in Fig. 4. In this embodiment, a segment of a elastic tubular conduit 605 is fixed to a base 610 by clips 615 so that the segment of the conduit 605 fixed to the base 610 has an "S" shape, as shown in Fig. 5b.

The pump 600 comprises two dual valves 620a and 620b. The dual valve 620a has two valve heads 625a and 625c, and the dual valve 620b has two valve heads 625b and 625d. The dual valves are fixed to the base 610 via a bracket 630 so that the valve heads 625a, 625b, 625c and 625d are located over the points a, b, 5 c, and d, respectively, along the conduit 605. Each of the valve heads 625 has an up position in which the lumen in the conduit 605 under the valve head is open allowing fluid flow, and a down position in which the lumen under the valve head is obstructed, preventing fluid flow. The design of the dual valve 620a is shown schematically in Fig. 6. The valve heads 625a and 625c are attached to opposite 10 ends of an iron bar 635. The lever bar is pivotable around an axle 645. When the lever bar is in the configuration shown in Fig. 6a, the valve head 625a is in its up configuration, and the valve head 625c is in its down configuration. When the lever bar is in the configuration shown in Fig. 6b, the valve head 625a is in its down configuration, and the valve head 625c is in its up configuration. Movement 15 of the lever bar is controlled by an electromagnet 640. A "U" shaped iron bar 642 passes through the interior of a wire coil 647. A pair of permanent magnets 650a and 650b are attached at either end of the lever bar. When current flows in one direction in the coil 647, the lever bar assumes the configuration shown in Fig. 6a. Attraction between the magnet 650a and the bar 642 latches the lever bar in this 20 configuration. When current flows in the other direction in the coil 647, the lever bar switches to the configuration shown in Fig. 6b. Attraction between the magnet 650b to the bar 642 latches the lever bar in this configuration. Operation of the dual valve 620b is similar to that just described for dual valve 620a.

Due to the construction of the dual valve 620a, the valve head 625a and 25 625c are never both open or closed simultaneously. Similarly, the valve heads 625b and 625d are never both opened or closed simultaneously. Note that in the temporo-spatial array of valve positions shown in Fig. 4 that is to be executed by embodiment, valve heads a₁ and a₃ are never open or closed simultaneously. This also applies to valves a₂ and a₄.

Fig. 7 shows another embodiment of a pump in accordance with the invention that executes the temporo-spatial array of valve activation shown in Fig.4. In this embodiment, a lever 810a is rotatable around a pivot 815a. The lever 810a has a notch 820a at a notched end 825a that is close to the center of the pump 5 800.. The lever 810a is pivotable around the pivot 815a from a first position in which the notch 820a is lowered as shown in Fig. 7, and a second position in which the notch 820a is raised (not shown). The position of the lever 810a is determined by a pair of electromagnets 805a and 806a. When the electromagnet 805a is activated, the lever 810a assumes its first position in which the notch 820 is lowered. A permanent magnet 840a latches the lever 810a in this position. When 10 the electromagnet 806a is activated, the lever 810a assumes its second position in which the notch 820 is raised. A permanent magnet 842a latches the lever 810 in this position.

A second lever 845a has a first valve head 855a and a second valve head 15 856a. The lever 845a is rotatable about a pivot 850a from a first position in which the valve head 855a is higher than the valve head 856a, as shown in Fig. 7, and a second position in which the valve head 855a is lower than the valve head 856a. The lever 845a includes an extension 860a having a terminal projection 865a that 20 mates with the notch 820a. The position of the lever 845a is determined by the position of the lever 810a. When the lever 810a is in its first or second position, the lever 845a is also in its first or second position, respectively.

Another lever 810b is rotatable around a pivot 815b. The lever 810b is pivotable around the pivot 815b from a first position in which a first end 825b is raised, as shown in Fig. 7, and a second position in which the first end 825b is 25 lowered (not shown). The position of the lever 810b is determined by a pair of electromagnets 805b and 806b. When the electromagnet 806b is activated, the lever 810b assumes its first position. A permanent magnet 842b latches the lever 810b in this position. When the electromagnet 805b is activated, the lever 810b

assumes its second position. A permanent magnet 840b latches the lever 810b in this position.

A lever 845b has a first valve head 855b and a second valve head 856b. The lever 845b is rotatable about the pivot 815b from a first position in which the valve head 855b is higher than the valve head 856b, as shown in Fig. 7, and a second position in which the valve head 855b is lower than the valve head 856b. When the lever 810b is in its first or second position, the lever 845b is also in its first or second position, respectively.

The temporo-spatial array of activation of the four electromagnets 805a, 10 806a, 805b, and 806b, is determined by a driver (not shown) so as to activate a predetermined temporo-spatial array of valve head positions. Valve heads 855a, and 856a are never open or closed simultaneously. The same also applies to 855b and 856b. This is consistent with the temporo-spatial array of valve head activation shown in Fig. 4.

15 Fig. 8 shows the pump 800 in conjunction with an elastic tubular conduit 905. The tubular conduit 905 is held in a sleeve 910. The sleeve 910 is reversibly attached onto the pump 800 so that when the lever 845a is in its first position, the segment of the tubular conduit 905 adjacent to the valve head 855a is unobstructed while the portion of the tubular conduit 905 adjacent to the valve head 856a is 20 obstructed. The conduit 905 is adapted at each of its end to mate with extension conduits (not shown), for example, by means of male and female luer fittings at either end. The conduit 905 and the sheath may be provided as a single disposable unit.

Fig. 9 shows schematically another embodiment of a pump in accordance 25 with another embodiment of the invention. This embodiment, generally indicated by 915, is used for generating fluid flow in an elastic tubular conduit 920 having a section 930 of large cross sectional area (referred to herein as the "*expanded section*"), flanked by regions 935a and 935b of small cross section area (referred to herein as the "*narrow sections*").

The pump includes one or more valves 925 that are positionable adjacent to the expanded section 930 of the conduit 920. Valves 940a and 940b are positionable adjacent to the narrow section 935a and 935b, respectively. Four valves 925 are shown in Fig. 9. This is by example only, and any number of valves 925 maybe 5 used as required by any particular application. The valves 925 and the valves 940 may have for example, the structure described above in reference to Fig.2. Each of the valves 925 has a valve head 927, and each of the valves 940 has a valve head 942. The valve heads 927 have an up position in which a portion of the expanded section 930 adjacent to the valve is not obstructed, and a down position in which a 10 portion of the expanded section 930 adjacent to the valve is at least partially obstructed. The valve heads 927 may have the same stroke length (the distance traveled by the valve head between its up position and its down position), or the valve heads 927 may have different stroke lengths. The valves 925 may be positioned in any array adjacent to the expanded section 930 (i.e. in a straight line, 15 or in a random array). Due to the large cross sectional area of the expanded region 930, when a valve head 927 is in its down position, flow of the fluid in the expanded region 930 is possible around the valve head.

Electric power from a power supply (not shown) is distributed among the valves 925 and 940 according to a predetermined temporo-spatial array by a driver 20 unit (not shown).

When a valve head 942a or 942b is in its down position, the segment of the narrow region 935a or 935b, respectively, is obstructed. In use, a valve head 942a or 942b is brought to its down position so as to obstruct the narrow section 935a or 935b, respectively. One or more of the valve heads 927 are then brought to their 25 down position so as to decrease to volume of the expanded section 930. The valve heads 927 may be brought to their down position, for example, either simultaneously or sequentially. When the valve head 942a is in its down position and the valve head 942b is in its up position, lowering one or more of the valve heads 927 will cause fluid to flow from the expanded section 930 in the narrow

section 935b of the conduit 920. Similarly, when the valve head 942b is in its down position and the valve head 942a is in its up position, lowering one or more of the valve heads 927 will cause fluid to flow from the expanded section 930 in the narrow section 935a of the conduit 920. The pump 915 may thus be used to 5 generate a flow from the expanded section 930 to either one of the narrow sections 935.

Two or more pumps of the invention may be used simultaneously in a pumping system. For example, two pumps may be positioned in series along a conduit, or may be positioned in parallel along two branches or tributaries of a 10 conduit.

The pump of the invention may also be equipped with a communications device for transmitting information relating to the pump to a remote receiver. The transmitted information may include, for example, the volume that has been pumped, or the occurrence of a malfunction in the pump.

CLAIMS:

1. A pump for generating fluid flow in an elastic tubular conduit having a lumen, comprising:
 - (c) a plurality of electrically operated valves, each valve being positionable adjacent to the conduit, each valve having a valve head, the valve head configured to alternate from a first position in which the lumen of the conduit adjacent to the valve head is unobstructed and a second position in which the lumen of the conduit adjacent to the valve head is obstructed;
 - (d) a driver configured to control the positions of the valve heads, so as to execute a predetermined temporo-spatial array of valve head positions.
2. The pump according to Claim 1, in which each valve further comprises a permanent magnet attached to the valve head and an electromagnet having a wire coil operatively coupled to the valve head, so that when current flows in the coil in a first direction, the valve head assumes its first position, and when current flows in the coil in a second direction, the valve head assumes its second position.
3. The pump according to any one of the previous claims, wherein the valve heads have a first dimension positionable perpendicular to the axis of the conduit and a second dimension positionable parallel to the axis of the conduit, the second dimension of all of the valve heads being equal.
4. The pump according to Claim 1 or 2, wherein the valve heads have a first dimension perpendicular to the axis of the conduit and a second dimension parallel to the axis of the conduit, and wherein the second dimensions are not all equal or the shape of the valve heads are not all the same.
5. A pump according to any one of the previous claims having $2n$ valves, $V_1, V_2 \dots V_{2n}$, $2n \geq 4$, wherein the valves V_k and V_{k+n} are operatively coupled so that the valve head of the valve V_k and the valve head of the valves V_{k+n} are not open or closed simultaneously for $k=1, \dots, n$.
6. The pump according to Claim 5 having a base configured to maintain a segment of the conduit in a straight line or in an S shape.

7. The pump according to Claim 5 or 6, wherein n=2.
8. The pump according to any one of the previous claims wherein the tubular conduit is held in a sleeve.
9. The pump according to any one of the previous claims wherein the tubular conduit is preloaded.
10. The pump according to any one of the previous claims wherein one or more valve heads is oblique to the conduit.
11. The pump according to any one of the previous claims for generating a flow in a tubular conduit, at least some of the valve heads being configured such that when the valve is in its second position, flow of fluid may occur around the valve head, the pump being configured such that at least three of the valve heads are arranged in a non-linear array.
12. The pump according to any one of the previous claims further comprising a communications device for transmitting information to a remote receiver.
13. A pumping system comprising two or more pumps according to any one of the previous claims.
14. The pumping system according to Claim 13 comprising two or more pumps in which at least two pumps are arranged in series.
15. The pumping system according to Claim 13 comprising two or more pumps in which at least two pumps are arranged in parallel.

For the Applicants,
REINHOLD COHN AND PARTNERS
By:



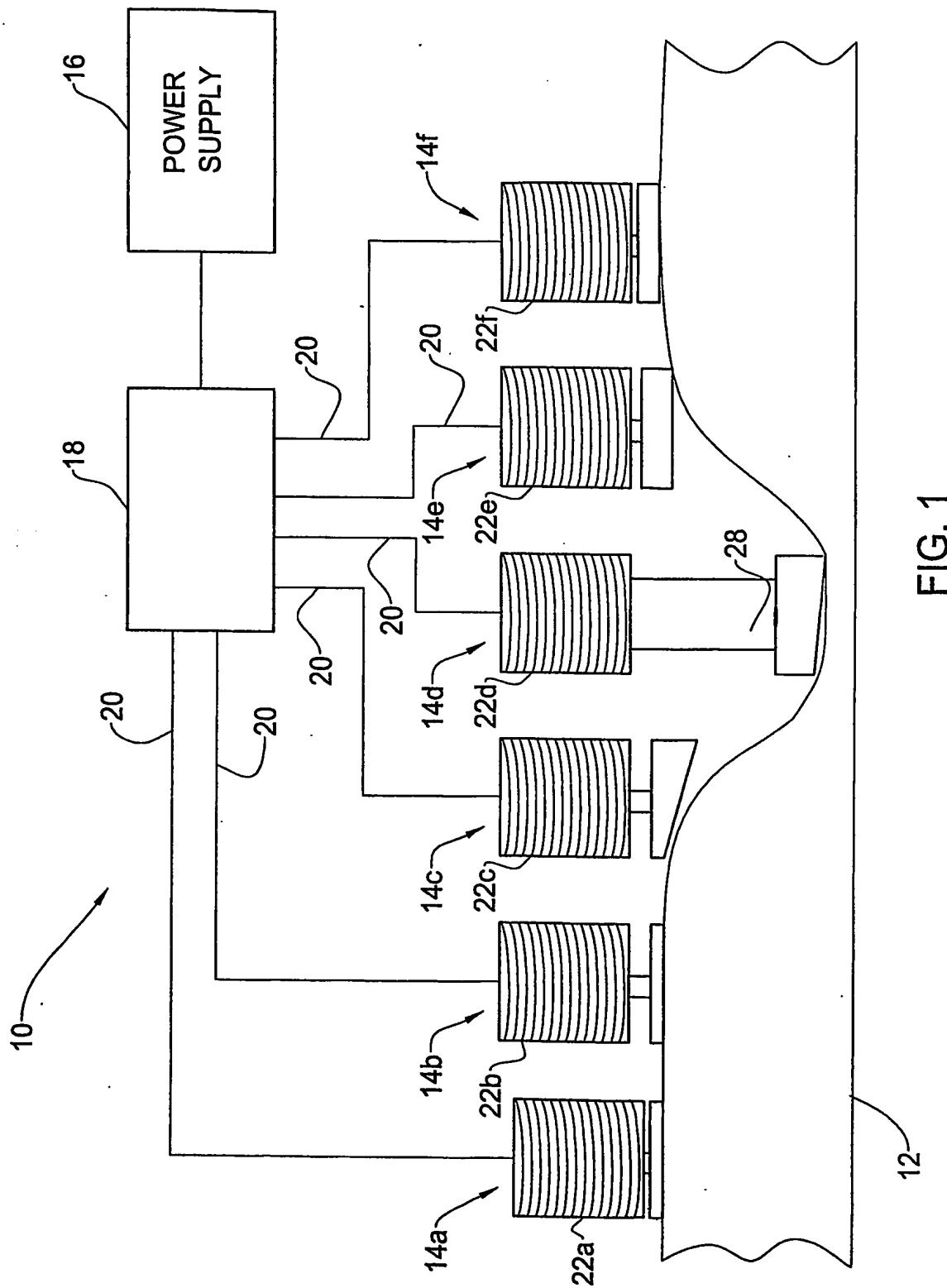


FIG. 1

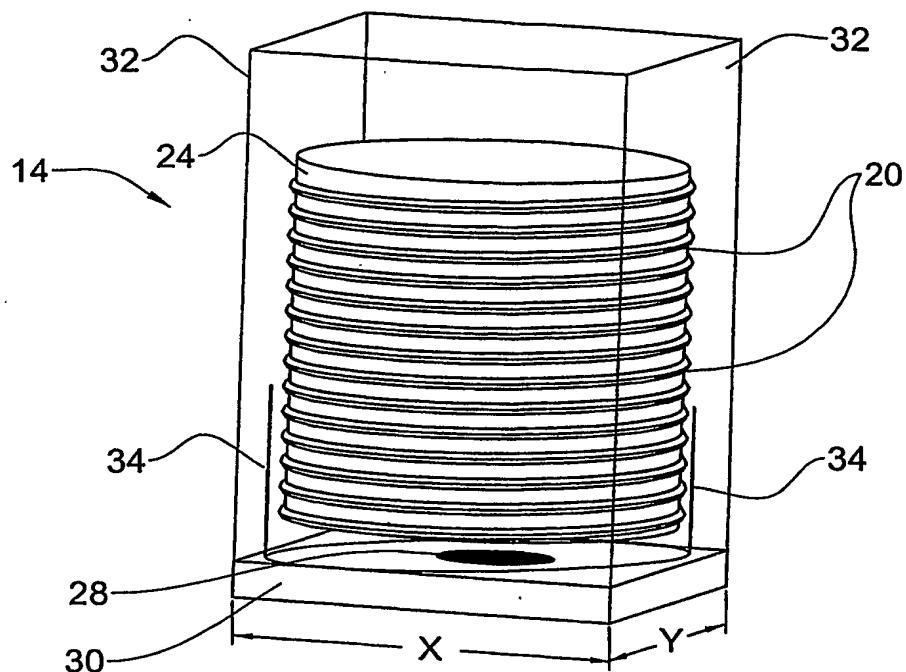


FIG. 2A

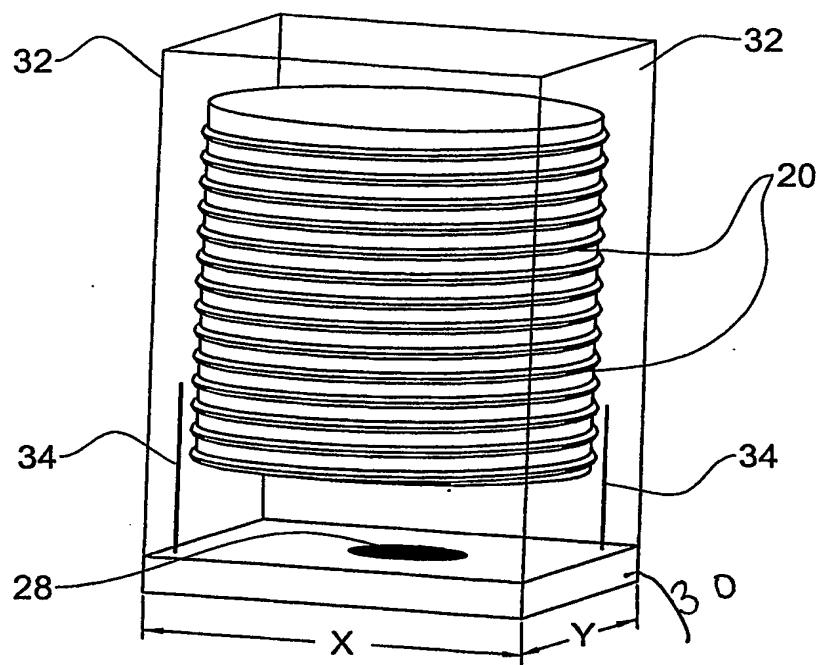


FIG. 2B

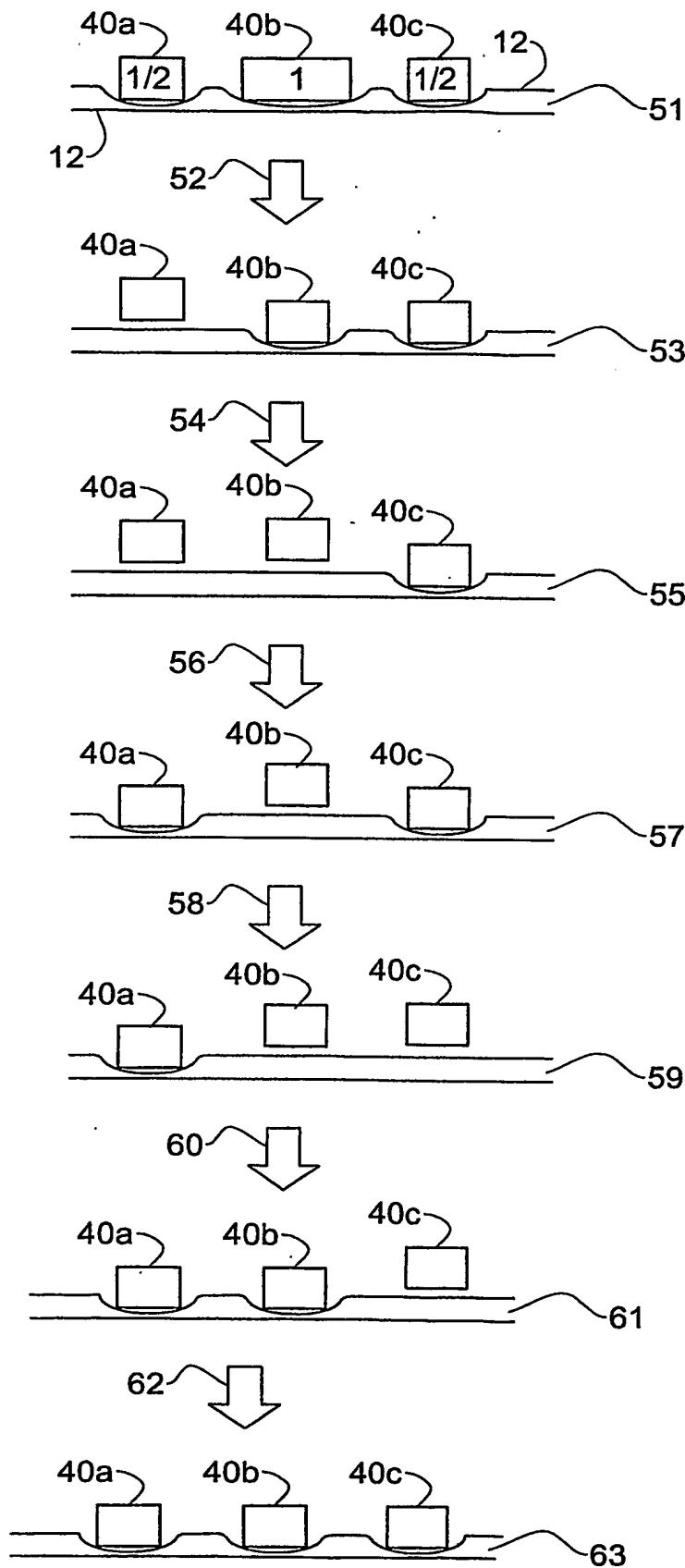


FIG. 3

a_1	a_2	a_3	a_4	
1	1	0	0	500
505				510
0	1	1	0	515
520				525
0	0	1	1	530
535				500
1	1	0	0	

FIG. 4

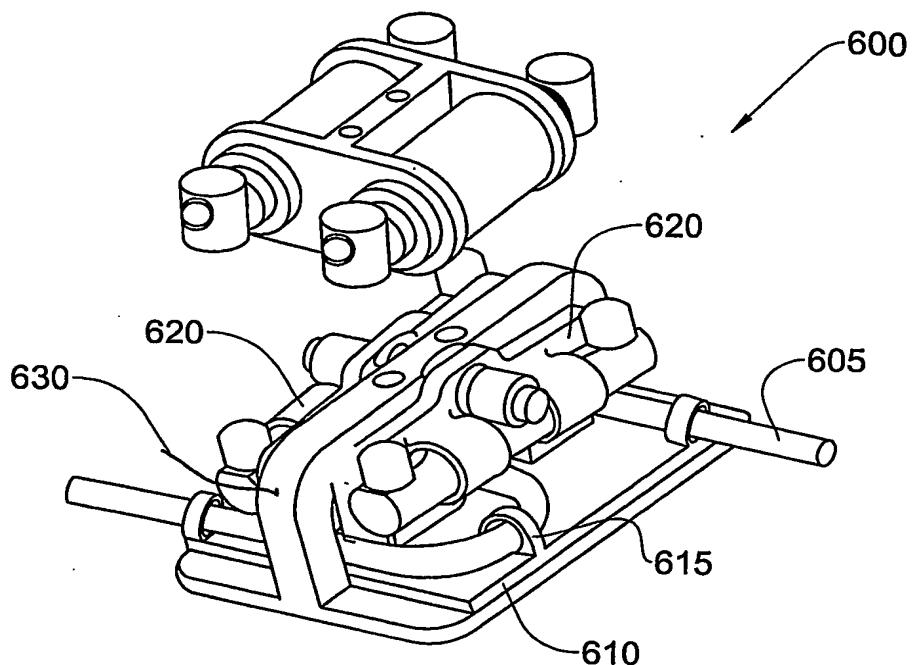


FIG. 5A

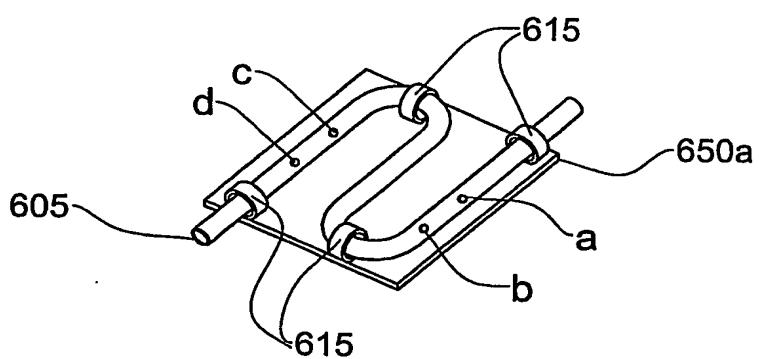


FIG. 5B

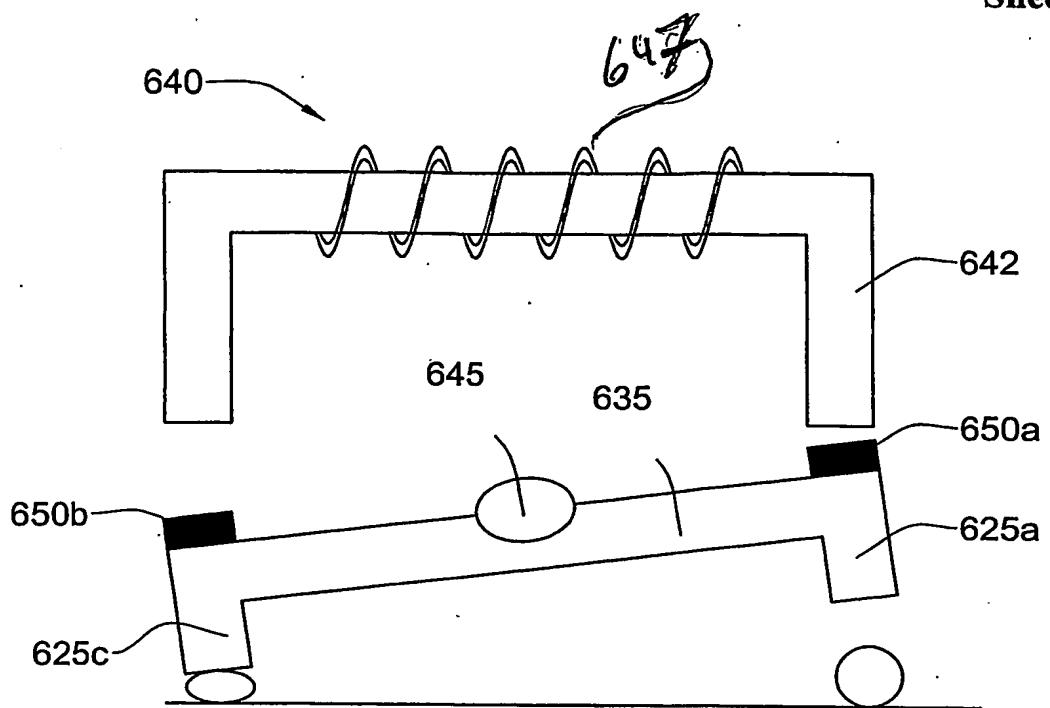


FIG. 6A

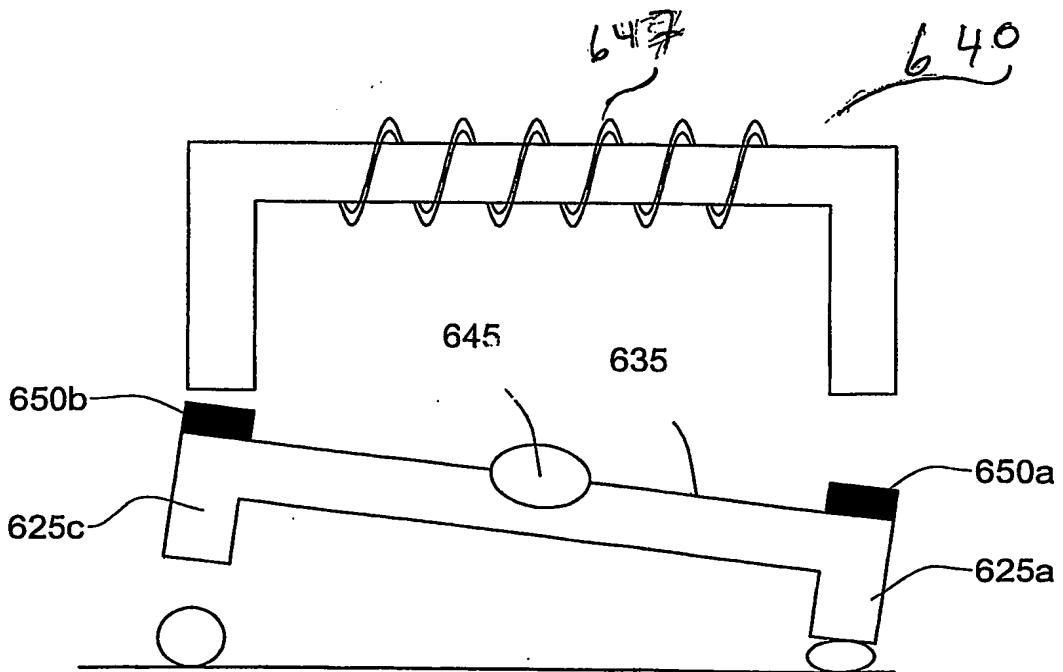
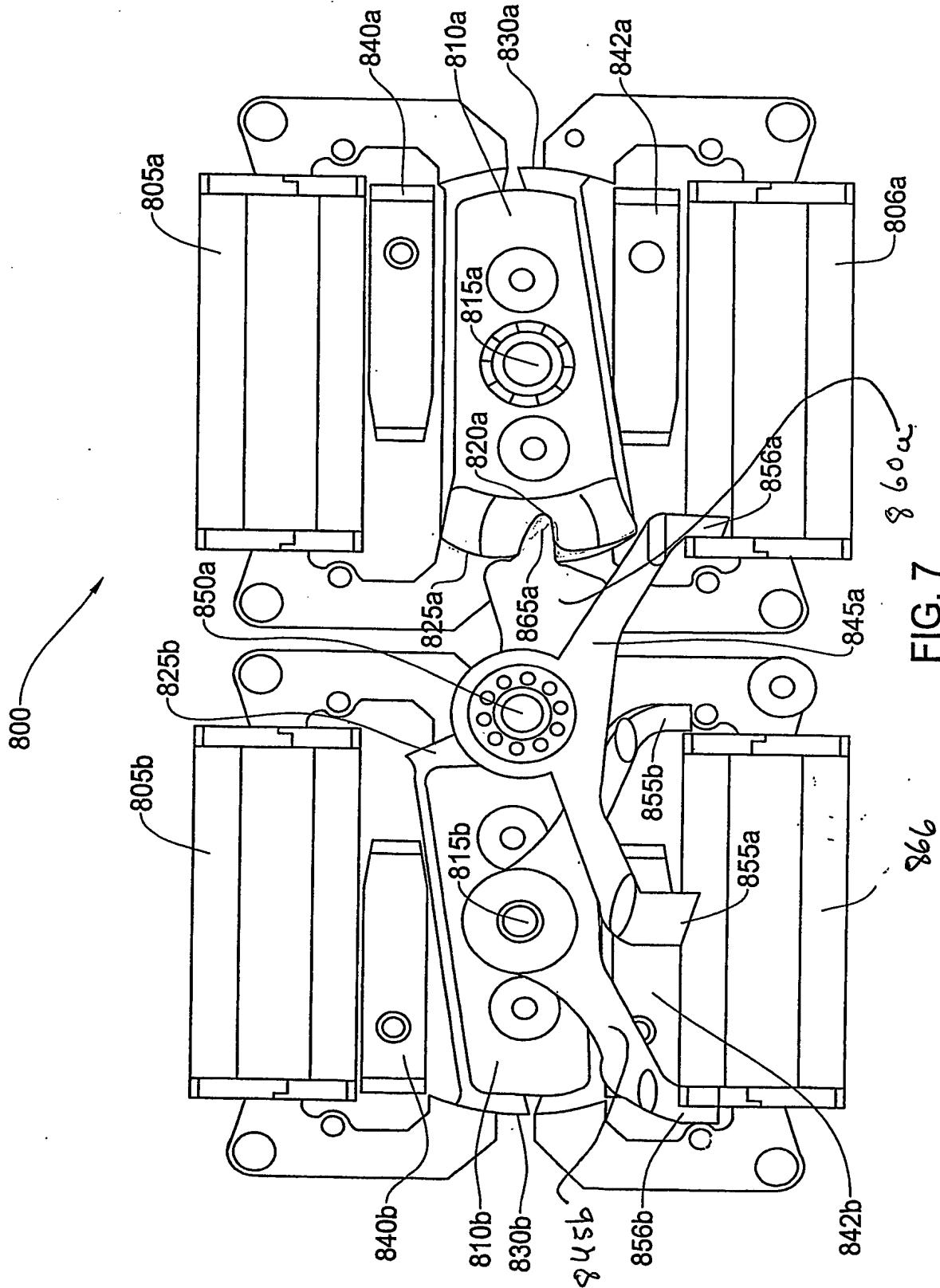


FIG. 6B



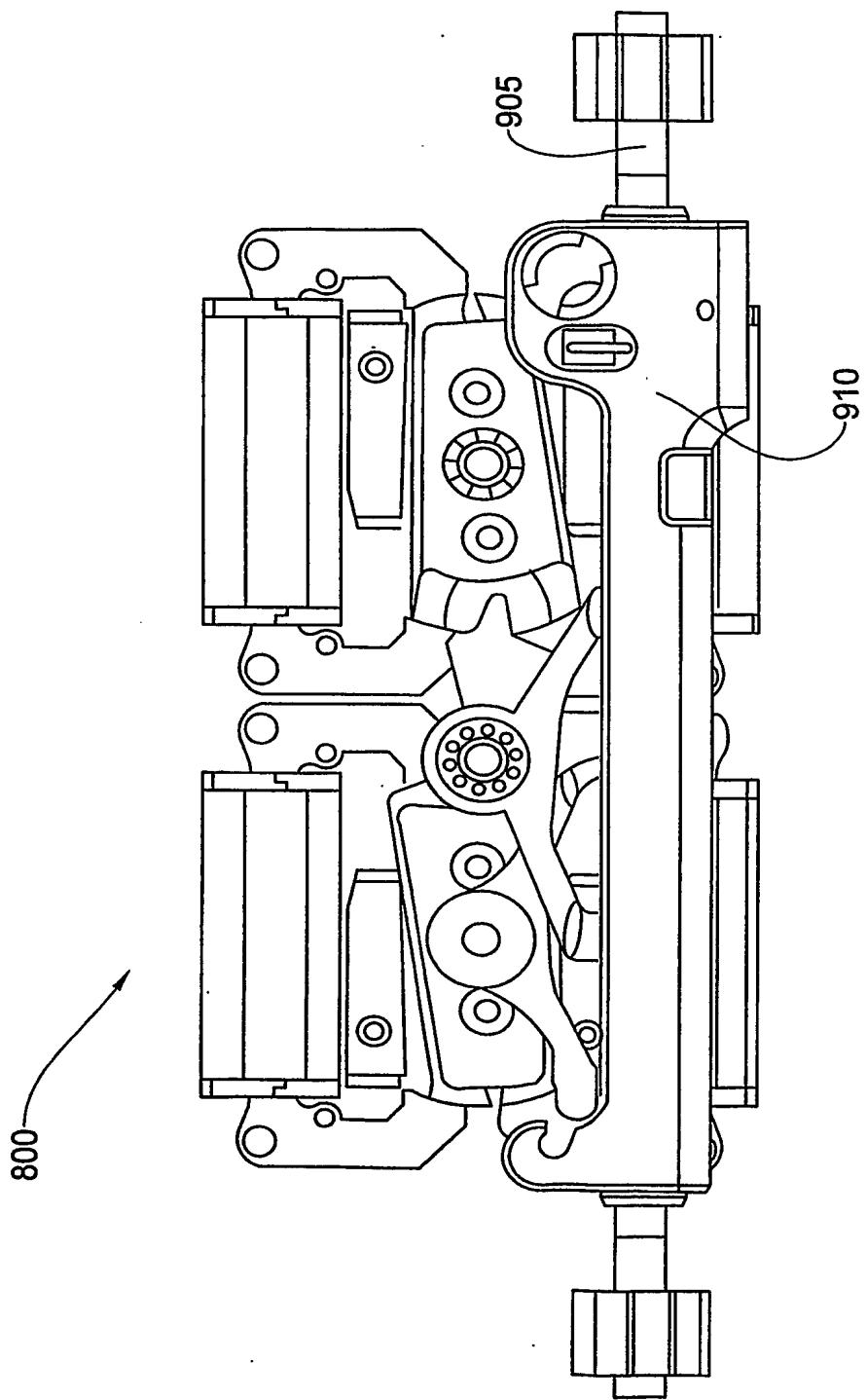


FIG. 8

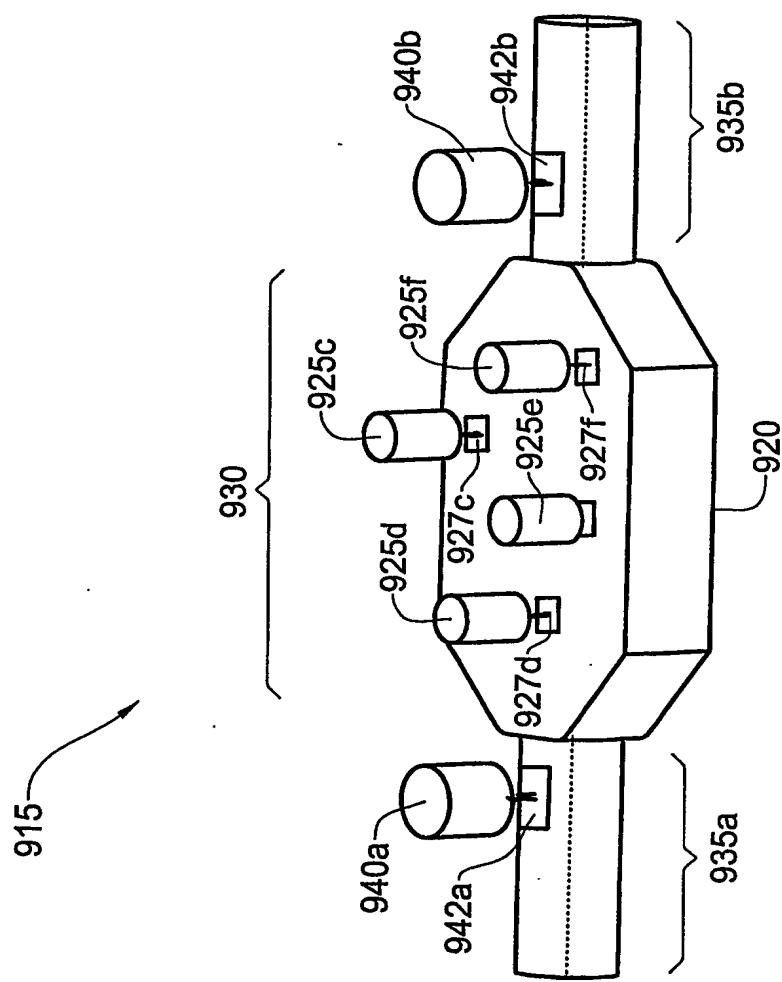


FIG. 9